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Observations

of the

OWENS VALLEY RADIO OBSERVATORY

California Institute of Technology

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6. A CATALOG OF LINEAR POLARIZATION CHARACTERISTICS OF RADIO SOURCES IN THE WAVELENGTH RANGE 10 to 21 CM

by

D. Morris and G. L. Berge

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A CATALOG OF LINEAR POLARIZATION CHARACTERISTICS OF RADIO SOURCES IN THE WAVELENGTH RANGE 10 to 21 CM

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D. MORRIS AND G. L. BERGE

ABSTRACT

A list of linear polarization measurements for 66 radio sources is presented. It includes values for 39 sources not previously reported on, plus a more complete set of values for the sources previously described (Seielstad and Wilson 1963; Seielstad, Morris and Radhakrishnan 1963; Morris, Radhakrishnan and Seielstad 1964c).

The conclusions reached by Seielstad, Morris and Radhakrishnan (1964) and Morris and Berge (1964) are examined with the use of the additional data.

Of these sources, approximately 40 have been examined at three different wavelengths (10, 18 and 21 cm) and for those with appreciable polarization in this range the dependence of polarization on wavelength is given. The relationship between the major axis position angle and the intrinsic polarization angle of double radio sources is discussed.

I. INTRODUCTION

Seielstad, Morris and Radhakrishnan (1964) have summarized the linear polarization characteristics available for 30 radio sources. Several of these, as well as many new sources, have recently been examined for linear polarization with the primary aim of establishing reliable rotation measures for a large number of sources. The present paper describes these measurements. We now have rotation measures for 16 of the new sources, as well as improved values for some of the previously reported sources. Preliminary values of most of these rotation measures have already been published (Morris and Berge 1964), and in this paper we include the measured polarizations from which these values were deduced. There is also a short discussion of the wavelength dependence of the polarization.

II. OBSERVATIONS

The measurements were made with the interferometer at the Owens Valley Observatory. An antenna separation of 100 feet east-west was used for the observations at 21.6, 18.0, and 10.3 cm. A third of the 21.2-cm observations were made at 200 feet east-west separation and the rest at 100 feet east-west. The sources observed were chosen from the most intense in the list of Kellermann (1964), on the basis that they would not be appreciably resolved by the interferometer and that their positions were known to within ± 2 minutes of arc. The weakest sources examined have a flux density of 4 F.U. at 21 cm, but the majority have flux densities in excess of 6 F.U.

The observational technique has been described previously (Morris, Radhakrishnan and Seielstad 1964a). The sources Cas A, Cyg A, M 87, Orion A, Hydra A, M 17 and CTB 31 were used for calibration of the instrumental polarization on the assumption that they themselves were not polarized. At 10-cm wavelength, errors of ≤ 0.5% may arise, since Cygnus A shows polarization at this wavelength (Mayer, McCullough and Sloanaker 1964). In the case of M 87, at 21 cm and 18 cm, the polarized halo can cause incorrect calibration at an antenna separation of 100 feet east-west (Morris, Radhakrishnan and Seielstad 1964b). Hence for this separation, M 87 has been omitted from the calibrators used at these wavelengths.

At 21.2 cm and 18.0 cm, conventional crystal mixers were used on each antenna of the interferometer, but at 10.3 cm one of the crystal mixers was preceded by a parametric amplifier. The observations at 21.6 cm utilized a travelling wave maser. In all cases, the receiver bandpass included the two sidebands which were spaced 10 Mc/s on each side of the quoted frequency of observation. In most cases each source was observed for up to 8 hours at each wavelength, although when the maser was used this time was reduced substantially, even for the weakest sources studied.

Table 1 contains the measured fractional polarization and the position angle of the electric vector for each source. It includes all the measurements for previously unreported sources, as well as a more complete set of values for those sources described by Seielstad and Wilson (1963), Seielstad, Morris and Radhakrishnan (1963) and Morris, Radhakrishnan and Seielstad (1964c). (These previous measurements used an antenna separation of 200 feet east-west at 21.2 and 18.0 cm and both 100 and 200 feet east-west at 10.6 cm.) With the exception of the initial work of Morris and Radhakrishnan (1963) and the work on resolved sources reported in Morris, Radhakrishnan and Seielstad (1964b), the results of all polarization observations made at the Owens Valley Observatory are contained in Table 1.

The position angle of the electric vector has not been corrected for the effects of ionospheric Faraday rotation. The errors quoted (standard deviations) are the random errors due to receiver noise, and any systematic errors will probably be a few tenths of one per cent. The principle systematic errors will be due to incorrect calibration of the instrumental polarization (in the neighborhood of Cygnus A, for example), incorrect antenna pointing, and the effects of confusion. The latter will be most severe at

21 cm where the r.m.s. confusion level is ≤ 0.2 F.U. (Kellermann 1964), and if we can assume that this exhibits ≤ 5% linear polarization on the average, then the spurious polarization will amount to ≤ 0.25% of the weakest source observed (4 F.U.).

In Table 1 the antenna separation is specified for each entry. If measurements have been made at both separations then the two are listed separately. However, there should be no difference between the two or between these and single-antenna measurements unless there are resolution effects present. In no instance is the visibility amplitude known to be less than 0.70, but in several cases it is below 0.85. Such measurements may show resolution effects.

III. ANALYSIS OF THE OBSERVATIONS

From the observed values of fractional polarization and preferred direction of polarization given in Table 1, values have now been calculated, in the manner of Seielstad, Morris and Radhakrishnan (1964), for the rotation measure, intrinsic polarization angle, and mean depolarization rate in the interval 10-21 cm for all sources for which we have sufficient data. The calculated values are given in Table 2, together with some of the information on the source identifications currently available.

a) The Rotation Measures

Preliminary values of rotation measures have already been published in a previous communication (Morris and Berge 1964), and Table 2 contains values for an additional 4 sources--3C 88, 3C 231 (M 82), 3C 272.1 (M 84) and 3C 430, and also a revised value for 3C 287. In two cases (3C 219 and 3C 330) there are uncertainties in the choice of the correct rotation measure and this has been indicated in the footnotes to Table 2. The general conclusions of Morris and Berge (1964) remain unchanged.

It seems that the analysis in terms of rotation measures does not account for all features observed in some sources. The rotation measure for Cygnus A has been known to be anomalously large for some time (Mayer, McCullough and Sloanaker 1962) and it has been suggested that a large part of the rotation can be attributed to the interiors of the components (Seielstad, Morris and Radhakrishnan 1963; Haddock and Hobbs 1963). According to recent measurements (Haddock and Hobbs 1963), the relation between position angle and wavelength squared is not linear but contains sharp features or discontinuities. We find that 3C 345 may be similar in that it shows evidence of an anomolous rotation curve. Figure 1b displays the measured position angle of the electric vector plotted against the square of the wavelength. The long wavelength observations seem to define a definite straight line which does not, however, pass through the 3.75-cm point (Haddock and Hobbs 1963). This may be of importance in connection with the orientation to be attributed to the magnetic field within the double radio sources. This point is discussed later.

b) The Wavelength Dependence of Fractional Polarization

Seielstad, Morris and Radhakrishnan (1964) have suggested that the observed variation of polarization with wavelength is due to depolarization by Faraday rotation within the sources themselves. This suggestion was based on an inverse correlation between polarization and magnetic field strength (or emissivity) and a possible correlation between depolarization rate and magnetic field (or emissivity). It is unfortunate that for the majority of the additional sources in Table 2, little or no information is at present available on their emissivity. Emissivities are known for only 4 of these sources and consequently the conclusions of Seielstad, Morris and Radhakrishnan are unaffected.

In the case of Cygnus A it has been shown (Mayer 1963; Haddock and Hobbs 1963) that the fractional polarization does not decrease uniformly with increasing wavelength, but that in some wavelength ranges the polarization increases as the wavelength is increased. This behavior, together with the sharp features in the rotation curve, has been explained as an interference effect produced by the differential Faraday rotation in the two components of the source acting on the polarized radiation from these two regions (Haddock and Hobbs 1963). According to this picture, at some wavelengths the contributions from the two components are polarized parallel to one another and augment the total polarization, while at other wavelengths they are orthogonal and subtract to result in a reduced total polarization.

A few of those sources with detectable polarization at 21 cm show evidence of related behavior. In the wavelength interval 10-21 cm, the majority of sources exhibit a decrease in polarization with increasing wavelength (as indicated by a negative value for $\partial(\log_{10} m)/\partial\lambda$), but in some cases the reverse is observed. The experimental uncertainties are sufficiently large that any finer detail will go undetected, but doubtless will be found when more accurate measurements are available. The sources with positive values of $\partial(\log_{10} m)/\partial\lambda$ include 3C 33, 3C 78, 3C 286, 3C 454.1 and 3C 345. The latter source shows a quite pronounced effect (Figure 1a) and, as previously mentioned, exhibits an anomolous rotation curve.

IV. THE ORIENTATION OF THE MAGNETIC FIELD WITHIN THE "DOUBLE" SOURCES

It has been pointed out (Gardner and Whiteoak 1963) that the intrinsic polarization angle will differ by 90° from the mean direction of the magnetic field within the radio sources. This mean must allow for the distribution of brightness over the face of the source, and of course it is assumed that the observed radiation arises by the synchrotron mechanism. Gardner and Whiteoak (1963) found from a study of their data on the "double" sources that the difference in angle between the intrinsic polarization angle and the major axis, which we denote by ϕ, had a distribution with concentrations at 0° and 90°. They were therefore led to suggest that two distinct field orientations, differing by 90°, are to be found among the double radio sources.

Gardner and Davies (1964), on the other hand, have found values of $\phi \approx 0^\circ$ for the triple source MSH 13-33 and conclude that the magnetic field in the radiating regions of the source must be perpendicular to the major axis. They propose that this field orientation arises when the galactic or intergalactic field is compressed and carried outward from the parent galaxy by the two clouds of plasma ejected in opposite directions at the birth of the source. In addition, it was further proposed that this mechanism operates in all the double radio sources and that any deviations of ϕ from 0° are to be attributed to the operation of the random influences of irregularities in the intergalactic medium into which the radio sources are expanding. Presumably such influences will become more effective as the source expands and ages.

However, the data of Seielstad, Morris and Radhakrishnan (1964) show a pronounced concentration of the values of ϕ at 90° and it is difficult to attribute this to random effects. In addition, it is the sources with large brightness temperatures (presumably young sources) which have $\phi \approx 90^\circ$. This is illustrated in Figure 2, where the values of ϕ are plotted against brightness temperature as determined for a wavelength of 21 cm. These temperatures were calculated by the method of Maltby and Moffet (1962), using their angular size data and the flux density data of Kellermann (1964). The values of ϕ are listed in Table 2. They are taken mainly from Seielstad, Morris and Radhakrishnan (1964). The value for 3C 219 is derived from new data, the values for MSH 13-33 are from Gardner and Davies (1964) and the value for the outer components of Cen A has been estimated from the measurements of Cooper and Price (1962). It appears that $\phi = 0$ (for which the average magnetic field in the radiating regions is perpendicular to the major axis) is only observed in the low-brightness sources and that the high-brightness sources have their fields parallel to the major axis. The cross-over from one to the other occurs at a 21-cm brightness temperature of about 1000° K.

Although it may be that the magnetic field configuration does differ by 90° between high and low-brightness temperature sources, there are alternative explanations. One possibility is a model whose field configuration is valid for all double sources, in which each component of the source contains a region with its magnetic field predominantly perpendicular to the major axis and another region in which the magnetic field is aligned parallel to the major axis. The former region then corresponds to that proposed by Gardner and Davies (1964) and is characterized by relatively large fields and high-particle densities. The second region can perhaps be identified with the magnetic lines linking the former region with the parent galaxy. It is characterized by smaller field strengths and lower particle densities and hence exhibits much less Faraday rotation.

According to such a model, in the case of low-brightness sources no appreciable Faraday depolarization takes place in any part of the source at wavelengths between 10 and 21 cm. The regions described by Gardner and Davies (1964) are dominant in these cases because of their higher emissivity and thus should be responsible for the observed linearly polarized radiation. Hence the measured value of ϕ is 0°. At very short wavelengths, the high-brightness sources will behave in an identical manner. However, as observations are made at successively larger wavelengths, Faraday depolarization and possibly differences in spectral index will, at some critical wavelength, ensure that the region of Gardner and Davies is no longer dominant as far as the polarized flux density is concerned. Consequently the polarization vector will rapidly rotate through 90°. From this point onward, the polarized radiation originates predominantly in the second of the above regions, where there is still little Faraday depolarization. Consequently, if measurements of the direction of polarization made at wavelengths in excess of the critical wavelength are extrapolated back to zero wavelength, a value of 90° will be obtained for ϕ.

If this model is correct, the high-brightness temperature sources should exhibit a rapid depolarization associated with a "flip" of 90° in the plane of polarization at short wavelengths. Cygnus A and 3C 345 may be such cases judging from their anomalous behavior at short wavelengths. However, it is not known whether 3C 345 has a high brightness temperature. In addition, at decimeter wavelengths the polarized emission of high-brightness sources should be more concentrated toward the central galaxy, relative to the unpolarized emission, than for low-brightness sources.

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Table 1

Linear Polarization in the Wavelength Range 10-21 cm
(Antenna Separation 100 ft E-W Unless Otherwise Indicated)

Source	21.6 cm		21.2 cm		18.0 cm		10.6 cm		10.3 cm	
	%	P.A.	%	P.A.	%	P.A.	%	P.A.	%	P.A.
M00-210			0.6±0.5	158°±25°	0.5±0.5	177°±24°				
3C 10			1.1 0.2	162° 5°						
3C 20			1.8 1.0*	126° 15°*						
M00-222			0.6 0.3	175° 13°	2.1 0.8	103° 11°			2.0±1.4	154°±21°
3C 27	6.0±1.0	118°± 5°	5.2 0.6*	124° 3°*	5.3 1.1	17° 6°			7.6 0.6	124° 3°
3C 33			7.7 0.7*	62° 3°*	7.2 0.6*	72° 5°*	8.0±1.3 4.9 1.8*	88°± 7° 96° 10°*		
3C 48			0.6 0.6 0.7 0.6*	154° 28° 162° 25°*	2.2 1.8	44° 25°	3.4 1.0*	75° 10°*		
3C 62	7.6 0.6	131° 3°	3.6 1.6*	130° 17°*	6.2 1.0	128° 6°			8.4 1.1	86° 4°
3C 78			2.9 0.9*	109° 9°*	2.5 0.6	114° 7°	2.3 1.7	85° 14°		
CTA 21			0.2 0.5	86° 72°						
3C 84			0.8 0.6*	37° 21°*	1.0 0.7*	172° 20°*	1.5 1.0 2.8 2.2*	102° 6° 125° 22°*		
3C 86	1.6 0.6	110° 10°	1.9 0.3	149° 6°	2.2 0.7	75° 8°			6.2 0.6	42° 3°
3C 88	4.0 0.6	129° 5°	2.4 2.0*	100° 24°*	6.1 0.6	121° 3°			2.3 1.1	87° 11°
3C 98			4.6 1.0*	62° 6°*	5.8 0.6*	16° 5°*	7.0 2.8	111° 11°		
3C 111	0.7 0.4	94° 17°	2.2 0.6*	92° 9°*	2.1 0.4*	120° 8°*	3.3 1.8	116° 14°		
3C 119			0.6 0.6*	36° 37°*	0.4 0.9	116° 67°				
3C 123			0.5 0.3 0.5 0.4*	177° 16° 68° 24°*			0.4 0.3*	69° 15°*		
3C 138	6.8 0.4	166° 2°	7.8 5.5*	170° 19°*	6.8 5.0	169° 21°			8.2 0.8	166° 3°
M05-36	3.5 0.2	92° 2°	2.1 0.4	95° 6°	2.1 0.3	86° 3°			4.1 0.5	72° 3°
3C 144[a]			1.3 0.1*	88° 1°*	1.8 0.1 1.8 0.3*	107° 1° 95° 5°*	3.9 0.2	124° 5°		
3C 147			0.6 0.3 0.2 0.5*	173° 10° 138° 57°*	0.7 0.3	113° 14°	0.9 0.9 0.7 1.2*	104° 18° 58° 46°*	1.0 0.6	129° 18°

Table 1 (continued)

Source	21.6 cm %	21.6 cm P.A.	21.2 cm %	21.2 cm P.A.	18.0 cm %	18.0 cm P.A.	10.6 cm %	10.6 cm P.A.	10.3 cm %	10.3 cm P.A.
3C 161			6.3±0.3 5.8 0.5*	20°± 1° 29° 3°*	9.2±0.3 9.0 0.7*	125°± 1° 122° 5°*	6.1±0.6 9.5 1.2*	161°± 5° 168° 5°*	10.0±0.2	159°± 1°
3C 171	3.7±0.9	50°± 7°								
3C 192	3.3 0.4	119° 4°								
3C 196	0.4 0.2	134° 11°	1.0 0.4 0.4 0.5*	150° 14° 155° 38°*	0.4 0.3	107° 22°	1.8 1.2 1.0 1.3*	85° 11° 95° 34°*	2.4 0.4	71° 5°
M08-219	1.9 0.4	48° 7°								
3C 218[b]			0.4 0.2*	124° 14°*					1.2 0.2	12° 4°
3C 216	1.0 0.5	96° 12°								
3C 219	2.9 0.3	99° 3°	3.0 0.3	114° 3°	3.2 0.5	125° 5°			3.3 0.9	127° 9°
3C 227			4.6 0.3	147° 3°	4.5 0.6	154° 4°	3.9 2.0	153° 16°	4.4 0.8	149° 6°
3C 231[c]	0.3 0.6	84° 50°	0.9 0.3	144° 10°	0.4 0.5	100° 36°	3.5 1.3	35° 11°		
3C 237			1.3 0.6	9° 10°	2.1 1.7	164° 20°			0.9 1.0	96° 26°
M11-118	2.7 0.3	158° 3°								
3C 272.1[d]	2.3 0.5	120° 7°	2.7 0.4	120° 5°	3.3 0.5	146° 5°			7.1 0.8	140° 4°
3C 273			2.2 0.2 2.2 0.1*	158° 3° 162° 2°*	3.0 0.4 2.4 0.5*	164° 3° 178° 7°*	3.4 0.3	147° 4°	2.5 0.4	154° 5°
3C 274[e]			0.5 0.1 0.3*	138° 7°	0.9 0.8	148° 22°				
3C 278	3.6 0.3	158° 2°	3.5 0.5	163° 4°	5.4 1.0	172° 4°			9.1 1.5	7° 4°
3C 279	6.6 0.4	149° 2°	5.1 0.3	152° 2°	6.3 0.5	138° 3°			5.9 0.6	94° 2°
3C 286			9.3 0.5*	32° 2°*	8.7 0.7*	34° 5°*	9.5 1.2 8.5 1.1*	30° 5° 28° 4°*		
3C 287	0.6 0.5	4° 23°	1.5 0.9	10° 14°	1.9 0.6	72° 8°			3.9 1.0	108° 7°
3C 295			0.2 0.2 0.5 0.5*	178° 22° 160° 27°*	0.3 0.5	162° 49°	0.4 2.0	72° 156°	1.3 0.7	75° 13°
3C 298	0.7 0.3	172° 11°								
3C 310			0.4 0.4	169° 24°	1.6 0.8	49° 16°			2.5 0.8	35° 11°
3C 317	0.5 0.3	72° 17°								

Table 1 (concluded)

Source	21.6 cm %	21.6 cm P.A.	21.2 cm %	21.2 cm P.A.	18.0 cm %	18.0 cm P.A.	10.6 cm %	10.6 cm P.A.	10.3 cm %	10.3 cm P.A.
3C 327	4.9±0.3	2°± 2°	3.7±1.6*	7°±14°*						
3C 330	3.1 0.5	160° 4°	4.5 0.4*	171° 3°*	4.3±1.0	155°± 7°			6.5±1.9	110°± 8°
3C 345	5.9 0.5	97° 2°	6.8 0.6	96° 2°	5.2 0.6	79° 3°			4.8 0.9	58° 6°
3C 348[f]			1.4 0.4*	59° 8°*	2.1 0.4*	52° 4°*	6.3±0.9	31°± 7°		
3C 353			2.9 0.4*	0° 4°*	3.8 0.5*	165° 6°*	6.7 0.6	114° 5°		
3C 358			0.8 0.3	57° 11°	1.1 0.4	70° 11°	0.8 0.9	117° 34°	0.6 0.7	21° 32°
3C 380	0.7 0.2	69° 7°	1.4 0.7*	72° 14°*	1.6 0.5*	34° 9°*	1.0 0.8	21° 24°		
3C 386	1.9 0.3	96° 4°								
3C 390			1.5 0.3	92° 5°	1.0 0.8	129° 27°			3.4 1.5	100° 10°
3C 391			0.7 0.3	128° 13°	0.4 0.3	132° 24°			1.3 0.3	27° 7°
M19-46			0.4 0.5*	9° 30°*	0.4 0.5	75° 37°			6.0 2.0	160° 9°
3C 403	3.5 0.3	137° 3°								
3C 409			1.1 0.4	178° 8°	1.2 0.5	106° 13°			0.4 0.8	24° 65°
3C 410	2.7 0.4	126° 5°	2.8 0.4	151° 4°	2.5 0.4	140° 6°			3.3 1.0	33° 9°
M21-21			1.4 0.3	34° 8°	0.9 0.6	161° 18°				
3C 430	3.2 0.5	64° 4°	2.1 1.7*	77° 20°*	2.1 1.2	20° 16°			4.9 1.0	43° 7°
3C 433			4.7 0.6*	150° 4°*	6.9 0.9*	26° 7°*	5.4 1.2 6.3 2.3*	121° 7° 123° 10°*		
3C 444			2.7 0.5 0.7 0.5*	8° 4° 177° 20°*	2.9 0.5	160° 5°			0.7 0.6	98° 19°
3C 446			5.2 0.5	113° 3°	4.1 0.5	136° 4°			4.2 1.2	177° 7°
CTA 102	4.8 1.0	106° 6°	3.7 0.5	110° 4°	5.2 0.3	155° 2°			5.7 0.5	18° 2°
3C 452			5.5 0.9*	23° 5°*						
3C 454.1			7.3 0.7*	65° 3°*	6.7 0.4	103° 2°			5.9 0.7	162° 3°

*Antenna separation 200 ft E-W.

a) Crab Nebula
b) Hydra A
c) M 82
d) M 84
e) Virgo A (M 87)
f) Hercules A

Table 2. Radio Source Properties*

Source	II (deg)	b^{II} (deg)	Rotation Measure (rad/m^2)	Int. Pol. Angle (deg)	Depol. $10\frac{\partial}{\partial\lambda}(\log_{10}m)$ (m^{-1})	Intrinsic Pol. Angle minus P.A. of Major Axis (deg)	21 cm Bright. Temp.[a] (^{o}K)	Luminosity[b] (ergs/sec)	Emissivity[c] (ergs/cm^3/sec)
3C 10	120	1			-33±10		2.5×10^{2}		
3C 27	123	6	-91±8	2±8	-11 6				
3C 33	129	-49	-10 2	101 6	+ 6 6	81	1.2×10^{4}	6.8×10^{42}	1.8×10^{-26}
3C 48	134	-28	-53 12	105 8	-65 35		$\geq5.0\times10^{7}$	4.7×10^{44}	$\geq8.4\times10^{-22}$
3C 62	181	-66	+32 8	72 10	-12 8				
3C 78	175	-45	+12 3	92 14	+ 7 7		4.3×10^{4}	1.8×10^{42}	7.9×10^{-27}
3C 84	151	-13	+55 8	76 10	-30 14		4.2×10^{3}	1.1×10^{42}	4.4×10^{-24}
(core)									
For A(a)[d]	240	-57	- 2 4	66 8	-11 5	15	20	5.9×10^{41}	2.8×10^{-29}
(b)			- 1 4	103 8	- 5 7				
3C 86	144	- 1	-400 15	100 10	-50 10				
3C 88	181	-42	+19 4	84 1	?			1.1×10^{42}	
3C 98	180	-31	+70 3	66 10	-17 10	41	1.0×10^{3}	1.5×10^{42}	2.9×10^{-27}
3C 111	162	- 9	-18 10	140 10	-30 25	80	1.9×10^{3}		
3C 138	187	-11			- 5 4				
M05-36	240	-32	+11 4	64 5	-18 10				
Pic A	251	-34	+45 4	110 10	- 7 10	20	9.0×10^{2}	1.2×10^{43}	$\geq7.8\times10^{-28}$
3C 144	185	- 6	-25 4	148 5	-37 13		1.6×10^{4}		
3C 161	215	- 8	+121 15	90 10	-18 6		1.6×10^{5}		
3C 196	172	33			-55 20				
3C 219	174	45	-10 8	140 10	- 4 4	72	1.3×10^{3}	4.0×10^{43}	1.2×10^{-27}
			(-278 10)[h]	(112 15)[h]					
3C 227	228	43	- 6 3	159 8	0 5	70	1.6×10^{3}	1.1×10^{43}	
3C 231	141	40	+50 15	2 15	-55 25		1.1×10^{3}	4.2×10^{39}	1.6×10^{-24}
3C 270	282	67	+ 4 2	105 10	- 7 7	20	6.2×10^{2}	2.1×10^{40}	1.1×10^{-27}
3C 272.1	280	74	-12 4	150 10	-41 7		4.4×10^{2}	1.7×10^{40}	
3C 273	290	64	+11 6	145 10	-22 12	79	$\approx2\times10^{6}$	3.1×10^{44}	1.9×10^{-23}
3C 278	304	51	-13 4	15 5	-38 8		3.6×10^{2}	2.3×10^{41}	7.2×10^{-28}

Table 2 (continued)

Source	II (deg)	b^{II} (deg)	Rotation Measure (rad/m^2)	Int. Pol. Angle (deg)	Depol. $10\frac{\delta}{\delta\lambda}(\log_{10} m)$ (m-1)	Intrinsic Pol. Angle minus P.A. of Major Axis (deg)	21 cm Bright. Temp.[a] (°K)	Luminosity[b] (ergs/sec)	Emissivity[c] (ergs/cm^3/sec)
3C 279	304	57	+28±4	81±6	- 5± 5		≥ $2x10^3$		
Cen A(a)[e]	310	20	-60 6	147 5	-32 20	80	$4.5x10^3$	$1.7x10^{41}$	$8.1x10^{-26}$
(b)			-68 8	56 10	-20 15		≈ 20		
(c)			-66 10	168 15	-15 15		≈ 15		$\approx 10^{-29}$
(Outer Sources)				13 15		8	≈ 10		
13S6A	310	2	+59 5	20 10	-55 20				
3C 286	57	81	+ 4 4	33 5	+12 12		$6.4x10^6$		
3C 287	20	81	+130 10	20 15	-39 15		≥$1.6x10^3$		
M13-33(a)[f]	313	28	-31 4	114 4	-22 6	12	≃ 10^2		
(b)			-31 3	125 3	-30 15	1	≃ 10^3		
(c)			-36 3	120 3	- 8 6	6	≃ 10^2		
3C 295	97	61			-58 29		$1.0x10^6$	$2.0x10^{45}$	$2.2x10^{-23}$
3C 310	38	60			-65 25		$2.0x10^2$	$3.0x10^{42}$	$1.3x10^{-27}$
3C 327	12	38	+16 3	145 5	- 6 8	55	$1.4x10^3$	$1.4x10^{43}$	$1.0x10^{-27}$
3C 330	99	41	+24 6[i]	100 10	-17 7				
3C 345	64	41	+21 3	43 8	+18 6				
3C 348	23	29	+16 4	21 7	-60 25	80	$1.9x10^4$	$1.6x10^{44}$	$9.2x10^{-27}$
3C 353	21	20	+37 4	87 3	-40 5		$6.1x10^3$	$7.2x10^{42}$	$6.0x10^{-27}$
3C 380	77	24	+33 6	162 10	0 20		$1.4x10^5$		
Cyg A[g]	76	6	1200	33	-173	76	$3.1x10^5$	$5.1x10^{44}$	$5.1x10^{-25}$
3C 390	41	6			-61 30				
3C 410	70	- 4	-216 20	177 10	-10 8				
3C 430	100	8	-162 15	139 20	-25 15			$3.2x10^{41}$	
3C 433	75	-18	-7.9 4	171 6	0 12		$4.4x10^4$	$1.8x10^{43}$	$9.8x10^{-26}$
M21-64	321	-41	30 3	28 5	-38 8				
3C 446	59	-49	-35 5	22 8	0 10				
CTA 102	78	-38	-44 7	61 10	- 7 7		≥ $2x10^3$		
3C 454.1	86	-39	-50 4	13 6	+ 9 9				
M23-64	314	-55	23 2	11 10	0 7				

Notes to Table 2

* The polarization information is derived mainly from the data of Table 1. However, for several of the sources taken from Seielstad, Morris and Radhakrishnan (1964) it is derived partly or wholly from Gardner and Whiteoak (1963).

a) Calculated from Maltby and Moffet (1962) and Kellermann (1964).

b) Matthews, Morgan and Schmidt (1964). (For a deceleration parameter $q_o = 0$.)

c) Volumes used in the calculation are from Seielstad, Morris and Radhakrishnan (1964) and Maltby, Matthews and Moffet (1963) and have been adjusted for the distances in Matthews, Morgan and **Schmidt** (1964) and for $q_o = 0$.

d) Fornax A (a) is the larger component at $03^h20^m.5$, $-37°18'$. (b) is the smaller one at $03^h22^m.7$, $-37°28'$.

e) Much of the information is from Cooper and Price (1962). (a) refers to the central components at $13^h23^m.2$, $-42°49'$. (The major axis of this system is at P.A. = 47°.) (b) is the region at 13^h24^m, $-42°30'$. (c) is the condensation at $13^h20^m.5$, $-44°25'$. The outer sources consist of (c) and its counterpart on the opposite side of the center. (The major axis of this system is at P.A. = 5°.)

f) From Gardner and Davies (1964). (a) and (c) are the outer components. (b) is the central component.

g) Polarization properties calculated from Mayer, McCullough and Sloanaker (1964); Hollinger, Mennella and Mayer (1963).

h) Possible alternative.

i) Possibly larger and negative.

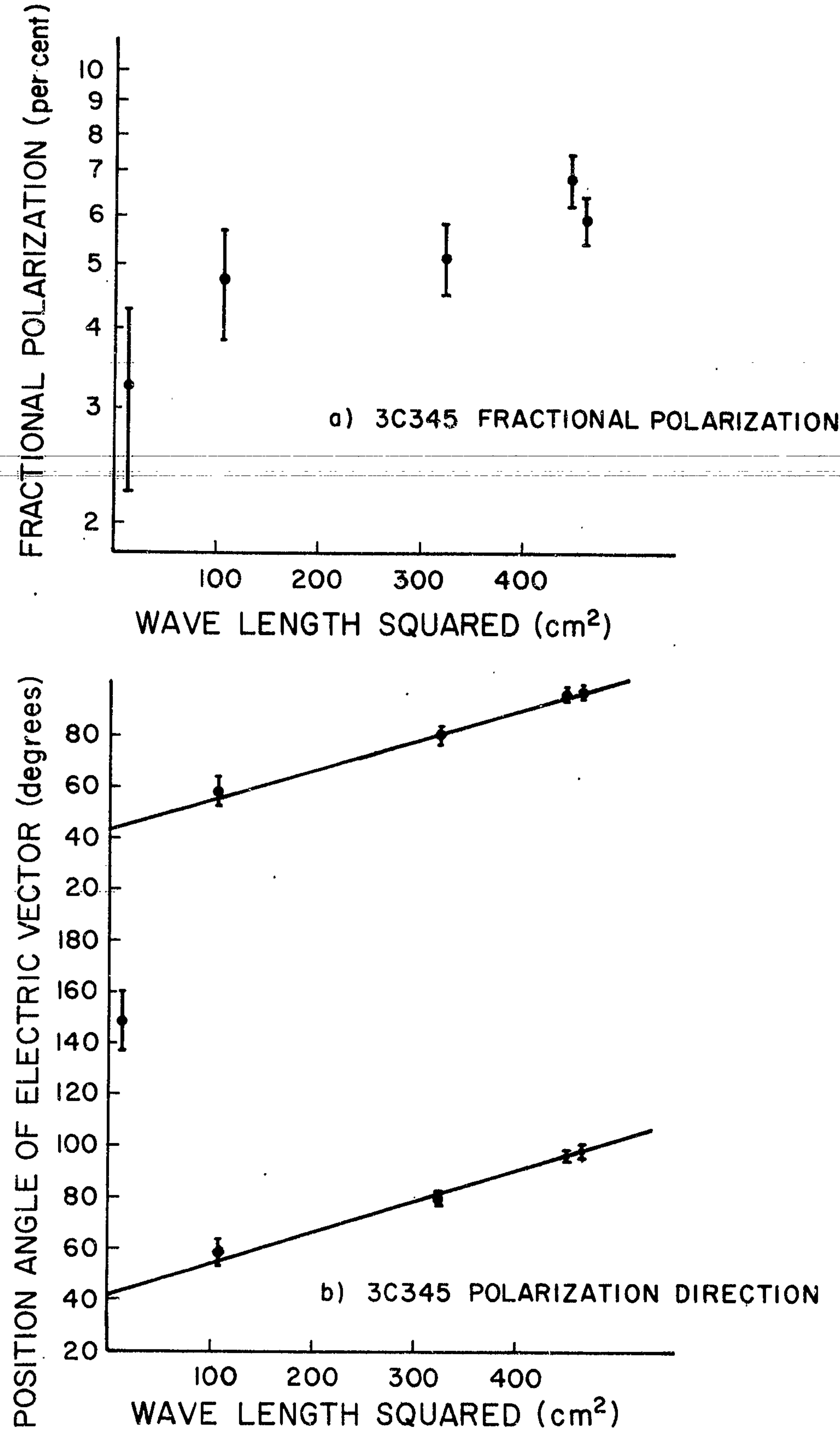

Figure 1. Measured polarization in 3C 345 as a function of wavelength squared.

(a) Fractional polarization versus wavelength squared.

(b) The position angle of the electric vector versus wavelength squared.

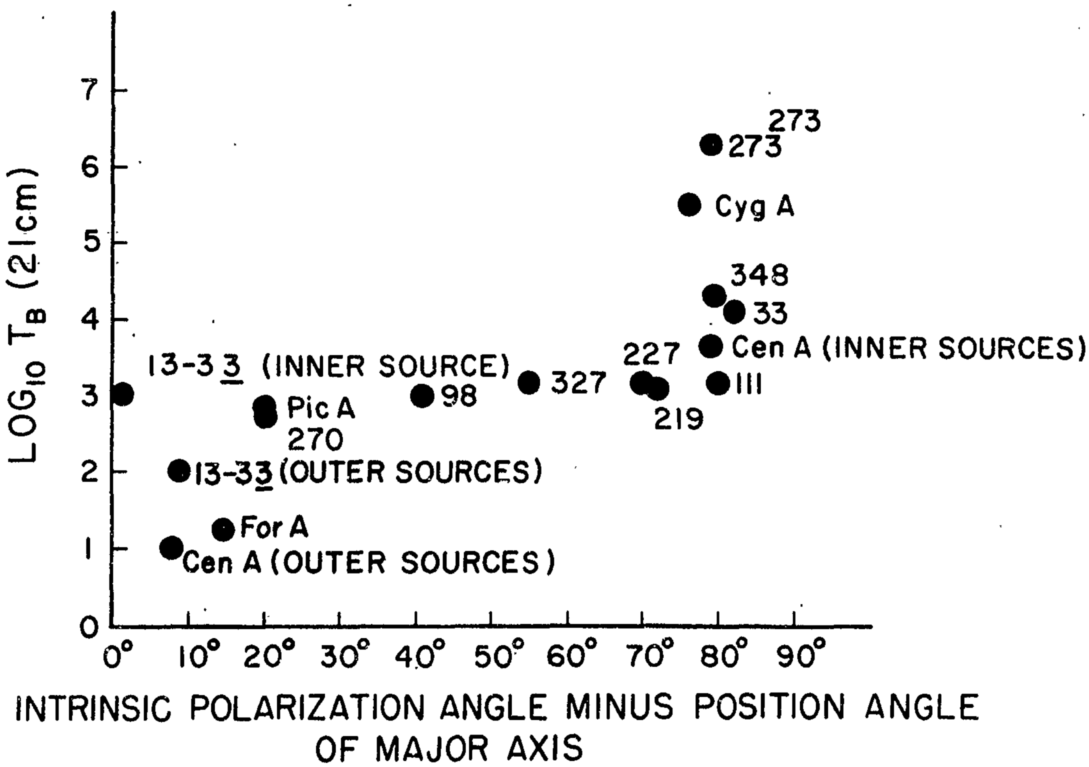

Figure 2. The difference in position angle between the intrinsic polarization angle and the major axis of the double sources plotted against the logarithm of the brightness temperature at 21 cm.